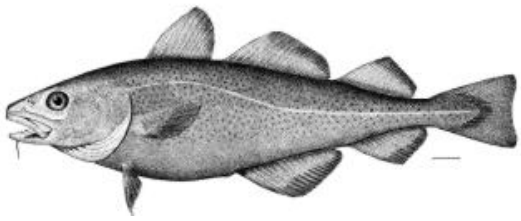

Atlantic Cod

by
Ralph Mayo and Loretta O'Brien

The Atlantic cod, *Gadus morhua*, is a demersal gadoid species found on both sides of the North Atlantic. In the Northwest Atlantic it occurs from Greenland to North Carolina. Cod may attain lengths of up to 130 cm (51 in.) and weights of 25 to 35 kg (55 to 77 lb). Maximum age is in excess of 20 years, although young fish (ages 2 to 5) generally constitute the bulk of the catch. Sexual maturity is attained between ages 2 to 4; spawning occurs during winter and early spring. Cod are omnivorous, feeding on a variety of invertebrates and fish species.

In U.S. waters, cod are assessed and managed as two stocks: Gulf of Maine, and Georges Bank and Southward. Both stocks support important commercial and recreational fisheries. Commercial fisheries are conducted year round, primarily with otter trawls and gill nets. Recreational fishing also occurs year round; peak activity occurs during the late summer in the lower Gulf of Maine, and during late autumn to early spring from Massachusetts southward.

Growth rates differ between the two stocks, although each is exploited by the same gear types with similar selection characteristics. Growth of cod has traditionally been slower in the Gulf of Maine than on Georges Bank but appears to have increased in recent years. Differences in growth rate by sex have also become less pronounced in both stocks.

United States commercial and recreational fisheries for cod are managed under the New England Fishery Management Council's Northeast Multispecies Fishery Management Plan (FMP). Under this FMP cod are included in a complex of 15 groundfish species which has been managed by time/area closures, gear restrictions, minimum size limits, and, since 1994, direct effort controls including a moratorium on permits and days-at-sea restrictions under Amendments 5 and 7 to the FMP. Trip limits are also in effect for both Gulf of Maine and Georges Bank cod. Amendment 9 established biomass rebuilding targets, and defines control rules which specify target fishing mortality rates and corresponding rebuilding time horizons. The goal of the management program is to reduce fishing mortality to levels which will allow stocks within the complex to initially rebuild above minimum biomass thresholds, and, ultimately, to remain at or near target biomass levels. The Canadian fishery on Georges Bank is managed under an individual quota system.

Total commercial cod landings from the Georges Bank and Gulf of Maine stocks in 1998 were 13,100 mt, a slight decrease from 15,800 mt in 1997, but 43% less than in 1994. United States

commercial landings in 1998 equaled 11,200 mt, 13% lower than in 1997, but 37% less than in 1994 (17,800 mt). Recreational cod landings totaled 1,300 mt in 1998, about 68% lower than the 1981-1997 average (4,100 mt).

Gulf of Maine

Total commercial landings (exclusively U.S.) in 1998 were 4,200 mt, a 22% decrease from 1997, and a 77% decrease from the record-high 1991 total of 17,800 mt. The 1998 U.S. landings were the lowest since 1966 and were well below the 1979-1988 average of 11,200 mt. The U.S. recreational catch of Gulf of Maine cod equaled 824 mt in 1998, well below the 1991 level (2,900 mt).

Northeast Fisheries Science Center (NEFSC) bottom trawl survey abundance and biomass indices declined to record low levels in both the autumn 1993 and spring 1994 surveys, and have since remained relatively low through autumn of 1998. Survey catch-at-age data indicate that the strong 1987 year class is no longer predominant, having been replaced by a series of average to below-average year classes from 1993 through 1997.

Fully recruited instantaneous fishing mortality (F) remained above 1.0 (58% exploitation rate) during 1994, 1995 and 1996, but declined to 0.82 (51% exploitation rate) in 1997 and to 0.64 (43% exploitation rate) in 1998. Despite these recent declines, fishing mortality since 1983 has generally been two to three times the level needed to attain 20% maximum spawning potential ($F_{20\%}$ = 0.36, 28% exploitation rate), the overfishing definition established for this stock , and well above F_{max} (0.27, 22% exploitation rate), the management target selected to allow the stock to rebuild under Amendments 5 and 7 to the Northeast Multi-species FMP.

Under Amendment 9 to the Northeast Multispecies FMP, overfishing occurs on this stock when the biomass-weighted fishing mortality rate exceeds $F_{THRESHOLD}$ which is, in turn, a function of mean stock biomass. In 1998, the biomass-weighted F corresponding to the fully-recruited F of 0.64 equaled 0.36, and the mean stock biomass was 11,800 mt. According to the SFA control rule, at this level of biomass, overfishing occurs if the biomass-weighted F exceeds 0.19. Thus, overfishing was occurring on the Gulf of Maine cod stock in 1998. As well, the stock is considered to be in an overfished condition when mean biomass is below 1/4 B_{MSY} (8,300 mt). Since the mean stock biomass was above 1/4 B_{MSY} in 1998, the stock was technically not considered to be in an overfished condition. However, current stock biomass is at its lowest level observed over the past two decades raising concern that 1/4 B_{MSY} may not be an appropriate measure of biomass to determine an overfished condition.

The 1987 year class (21.7 million fish at age 1) was the highest in the 1982-1998 series and about twice the size of the above-average 1980 and 1986 year classes. Recent recruitment, however, has been poor, and the 1993 through 1997 year classes (each about 3 million fish or less) are especially weak.

Spawning stock biomass (SSB) peaked in 1989 at 26,200 mt, following recruitment of the strong

1987 year class to the spawning stock. However, SSB declined to 10,700 mt in 1993, increased slightly in 1995, but has since declined to 10,000 mt in 1997, and to 8,300 mt in 1998. Given thesize of the incoming weak 1996 and 1997 year classes, SSB is not expected to increase appreciably in the near future even if fishing mortality is reduced substantially.

Thus, overfishing has been occurring on the Gulf of Maine cod stock and biomass remains at an extremely low level. Fishing mortality must be substantially reduced and remain low to prevent further stock declines and to promote rebuilding of spawning stock biomass.

Summary Status

Long-term potential catch (MSY)	=	10,400 mt
Biomass corresponding to MSY	=	B_{MSY} = 33,000 mt
Minimum biomass threshold	=	$^1/_4$ B_{MSY} = 8,300 mt
Stock biomass in 1998	=	11,800 mt (Implies stock was not overfished)
F_{MSY}[1]	=	0.31
F_{TARGET}[1]	=	0.29[2]
$F_{TARGET98}$[1]	=	0.15
Overfishing definition	=	$F_{THRESHOLD98}$[1, 3] = 0.19
F_{1998}[1]	=	0.36 (Implies overfishing was occurring)
Age at 50% maturity	=	2.5 yrs, males 2.2 yrs, females
Size at 50% maturity	=	38 cm (15.0 in.), males 33 cm (13.0 in.), females
Assessment level	=	Age-structured
Management	=	Northeast Multispecies FMP

M= 0.20 **$F_{0.1}$= 0.15** **F_{max} = 0.27** **F_{1998}[4] = 0.64**

[1] Weighted by stock biomass at age.

[2] Defined as lower 80th percentile of F_{MSY}

[3] $F_{THRESHOLD}$ = F_{MSY} = 0.31 on biomass when biomass = B_{MSY}. When biomass is between ½ B_{MSY} and B_{MSY}, $F_{THRESHOLD}$ is the maximum F that allows rebuilding to B_{MSY} in 10 years. When biomass is between $^1/_4$ B_{MSY} and ½ B_{MSY}, $F_{THRESHOLD}$ is the maximum F that allows rebuilding to B_{MSY} in 5 years. When biomass is below $^1/_4$ B_{MSY}, fishing mortality should be as close to zero as practicable.

[4] Fully recruited F

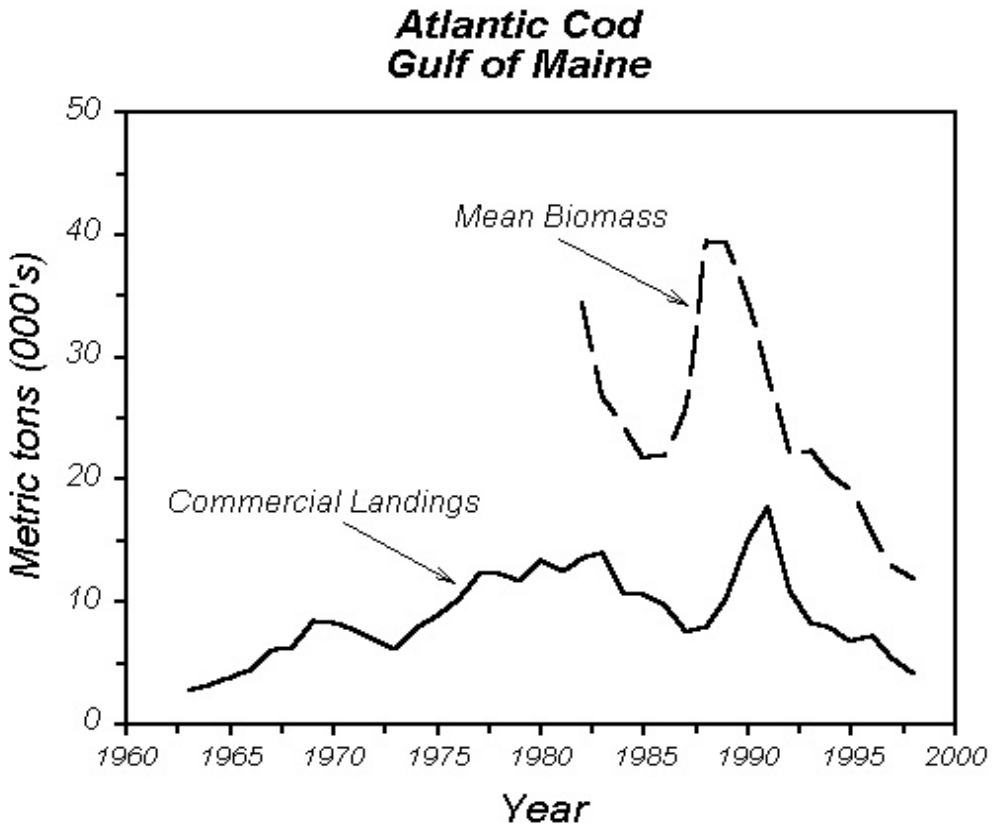

Table 1.1 Recreational and commercial landings (thousand metric tons)

		Year									
Category	**1979-88 Average**	**1989**	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**
U.S. recreational	2.1[1]	1.8	2.8	2.9	0.7	1.2	0.9	0.8	0.9	0.3	0.8
Commercial											
United States	11.2	10.4	15.2	17.8	10.9	8.3	7.9	6.8	7.2	5.4	4.2
Canada	<0.1	-	-	-	-	-	-	-	-	-	-
Other	<0.1	-	-	-	-	-	-	-	-	-	-
Total nominal catch	13.3	12.2	18.0	20.7	11.6	9.5	8.8	7.6	8.1	5.7	5.0

[1]1981-1988

Georges Bank and Areas to the South

Total commercial landings (U.S. and Canada) in 1998 were 8,900 mt, 14% less than in 1997, and about equal to 1996. The 1998 U.S. total (7,000 mt) is among the lowest in the time series, which dates back to 1893, and is well below the 1979-1988 annual average of 30,500 mt. Canadian 1998 landings totaled 1,900 mt, 35% lower than in 1997 and about equal to 1996. The 1998 U.S. recreational landings of 514 mt were well below the 1988-1997 average of 1,300 mt.

The NEFSC bottom trawl survey indices for spring and autumn increased from 1997 to 1998. The 1995 and 1996 year classes contributed to the higher indices in 1998 as above average survey catches of three- and two-year-old fish, respectively. Indices remain well below the long-term average and continue to indicate that the stock is at a low level.

Fully recruited fishing mortality declined from a record high of 1.39 (70% exploitation rate) in 1994 to F=0.28 (22% exploitation rate) in 1998. Fishing mortality was above $F_{0.1}$= 0.18 (15% exploitation rate), the management target selected to allow the stock to rebuild above the minimum spawning stock biomass threshold established under Amendments 5 and 7. The equivalent biomass weighted F of 0.24 in 1998 was above the control rule target and threshold F levels of 0.10 and 0.21, respectively. Mean biomass was estimated to be 36,300 mt, 34% of the biomass level needed to produce maximum sustainable yield. Based on Amendment 9 and the SFA control rules, overfishing was occurring on this stock as indicated by the level of the 1998 biomass weighted F. The stock was not overfished since the mean biomass was above the minimum biomass threshold of 1/4 B_{MSY} = 27,000 mt. However, the current mean biomass is among the lowest in the last two decades, which suggests that 1/4 B_{MSY} may not be an appropriate measure for determining an overfished condition.

The 1985 year class (42.8 million fish at age 1) was the largest in the 1978-1998 time series and the most recent above-average year class occurred in 1990 (18.0 million fish). All subsequent year classes have been near record lows and the 1997 year class (2.3 million fish) was the lowest in the time series. The 1998 year class (10.5 million fish) is below the long term average (16.0 million fish), but is the largest since the 1990 year class.

Spawning stock biomass increased from 55,500 to 72,100 mt between 1985 and 1989 due to recruitment of the strong 1983, 1985, and 1987 year classes. However, SSB has since declined, and in 1994 dropped to a record low of 21,000 mt. Spawning stock biomass has gradually increased to 28,700 mt in 1998, representing 41% of the minimum SSB threshold of 70,000 mt established under Amendments 5 and 7.

Overfishing has been occurring on Georges Bank cod and biomass remains at a low level. Recovery of the stock will depend on further reductions in fishing mortality as well as improved recruitment.

Summary Status

Long-term potential catch (MSY)	=	35,000 mt
Biomass corresponding to MSY	=	B_{MSY} = 108,000 mt
Minimum biomass threshold	=	$^1/_4$ B_{MSY} = 27,000 mt
Stock biomass in 1998	=	36,300 mt (Implies stock was not overfished)
F_{MSY}[1]	=	0.32
F_{TARGET}[1]	=	0.24
$F_{TARGET\ 98}$[1]	=	0.10
Overfishing definition	=	$F_{THRESHOLD\ 98}$[1, 2] = 0.21
F_{1998}[1]	=	0.24 (Implies overfishing was occurring)
Age at 50% maturity	=	2.1 yrs, both sexes
Size at 50% maturity	=	41 cm (16.1 in.), both sexes
Assessment level	=	Age structured
Management	=	Northeast Multispecies FMP

M=0.2 **$F_{0.1}$= 0.18** **F_{max} = 0.34** **F_{1998}[3] = 0.28**

[1] Weighted by stock biomass at age.

[2] When stock biomass is greater than B_{MSY} , fishing mortality is not to exceed $F_{THRESHOLD}$=F_{MSY}; when biomass is between ½ B_{MSY} and $^1/_4$ B_{MSY} F will be defined by a five year rebuilding time period and when biomass is between B_{MSY} and ½ B_{MSY} F will be defined by a 10 year rebuilding time period.

[3] Fully-recruited F

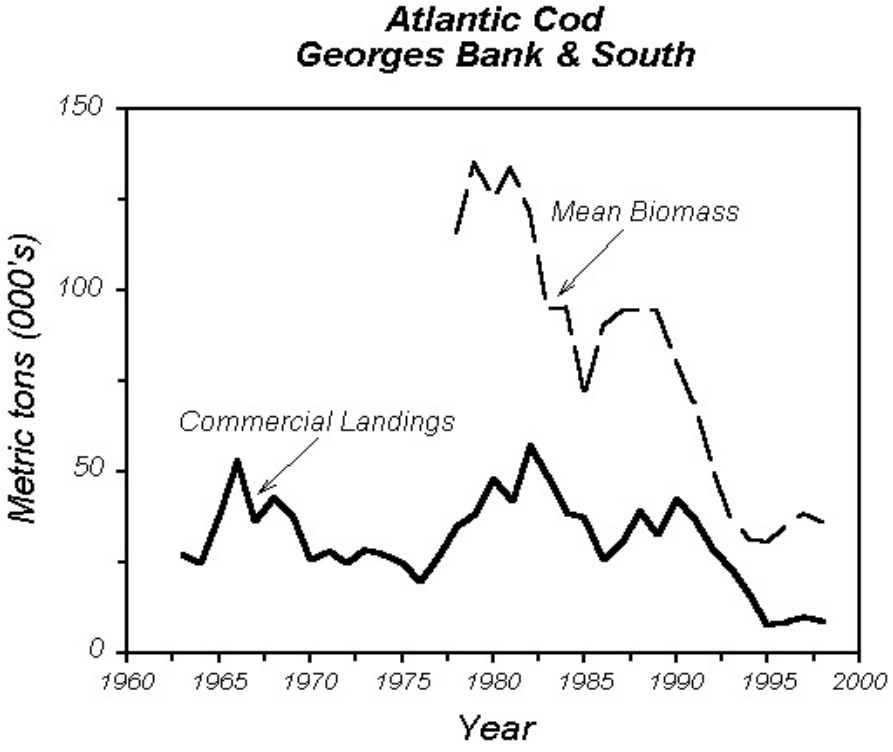

Table 1.2 Recreational and commercial landings (thousand metric tons)

Category	Year										
	1979-88 Average	**1989**	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**
U.S. recreational	3.9[1]	1.4	0.8	1.3	0.4	1.9	1.0	1.3	0.6	0.8	0.5
Commercial											
United States	30.5	25.1	28.2	24.2	16.9	14.6	9.9	6.8	7.0	7.5	7.0
Canada	10.2	8.0	14.3	13.4	11.7	8.5	5.3	1.1	1.9	2.9	1.9
Total nominal catch	44.6	34.5	43.3	38.9	29.0	25.0	16.2	9.2	9.5	11.2	9.4

[1]1981-1988

For further information

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